The future?

May 9, 2013
Sandeep wanted both of us to predict the future. Arun thought it would be boring if we both did it. So here I am. From Wikipedia: “Defined broadly, a visionary, is one who can envision the future. For some groups this can involve the supernatural. The visionary state is achieved via meditation, drugs, lucid dreams, daydreams, or art. Some people use mathematics to make visionary discoveries in the nature of the universe. “

• I am not really experienced or qualified in
• any of these fields above but I like math
I did not make this happen. It was here all along.

This is the “face” of a three machine system

90,000 point 3-D Poincare section

Actual computations from a three machine system

To establish my credentials. A computer aided vision?
A Warning

• “Prognostication is tricky business. So much is so well recorded these days that people who predict the future can actually be held accountable for what they say. ...Don't predict the future unless you can withstand the roasting that comes from being wrong, or have a team of spin experts who can actually show you were right. ” Jason Ohler writer
Just doing our job

• The idea of a linear state estimator was very early in PMU history: it is in the ‘88 relaying book. We tried to convince South Korea 20 plus years ago (who didn’t have a State Estimator) to go straight to linear. They asked who else was doing it and we had to say no one, they could be first. They were not interested in being first. So if there are any true visionaries here they must be from Dominion

• A reviewer of one of our recent (unfunded) proposals said we were addressing the current power system and there was no point in that since the new Smart Grid, rich in renewable energy, was right around the corner.
Right around the corner?

- The massive investment in ~ 372,340* miles of transmission and countless generation sites make it unlikely we will abandon them all. T. Boone Pickens has learned transmission still matters.
- The less than speedy acceptance of synchrophasors makes me wonder about anything being right around the corner.
- A member of the NAE said in the 80’s that PMUs were too accurate. We did not know the power system well enough.
- The CIGRE representative for Great Britain said in the same period that there would never be a digital relay in England.
Why it’s hard

It’s one thing to talk about what should happen or what is technically possible and another to predict the future because so many non technical things intervene.

To have predicted in 2003 that we would have 1000 PMUs by 2013 would have required fore knowledge of a financial collapse, an unlikely (in 2003) election result, and a stimulus program.
But other people have no fear about making predictions.

Presented at National Press Club in Dec 2011. The second question from the audience was whether the federal government could regulate the flow of electricity since there was no electricity when the constitution was written. An MIT professor answered that electrons had been observed crossing state lines.

The future:
Findings from “The Future of the Electrical Grid” MIT 2011 Study

300 pages, scores of contributors
• “PMUs could improve the performance of energy management systems by providing real-time data to determine system state faster and more accurately than current estimation tools. A more extensive deployment of PMUs is required to make this possible”.

• “Automatic control action based on real-time data from a wide-area network of PMUs represents a major change in system operations. Today such system are limited in number and capability. Significant research in control algorithms and improved confidence in the reliability and accuracy of PMU data is needed to make such control more prevalent.”

First prediction: we will make progress on both issues

The future: Findings from “The Future of the Electrical Grid” MIT 2011 Study concerning PMUs
• “Research and development efforts should be undertaken to develop 1) the analysis tools necessary to generate actionable information from data acquired from PMUs and 2) the control schemes necessary to make use of this information by realizing the complementary potential of PMUs, FACTS, and other hardware devices.

• “NERC should continue to encourage relevant entities to participate in PMU data-sharing efforts necessary for the effective development and use of PMUs and wide area measurement systems.”

Recommendations from “The Future of the Electrical Grid” MIT 2011 Study concerning PMUs
The past

I discovered at Cornell that students enjoyed hearing about how badly the future had been predicted in the past and what dumb thing we had done and how old I was in terms of things they understood.

I was a student when Sputnik was launched (1957).

I got tenure before Prof Shukla was born.

I took a course in making vacuum tubes – there were no transistors.

I owned a wire recorder – there was no magnetic tape.
I was a member of the Cornell Rocket Club. We had our own bunker. We needed it. Launches were dangerous. But that was common in those days. Vangard 1957
Well known examples of errors in predicting the future-technical

- "I think there is a world market for maybe five computers." -- Thomas Watson, chairman of IBM, 1943.
- "Where a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and weigh only 1.5 tons." -- Popular Mechanics, 1949
- "There is no reason anyone would want a computer in their home." -- Ken Olson, president, chairman and founder of Digital Equipment Corp., 1977.
- "640K ought to be enough for anybody." -- Attributed to Bill Gates, 1981, but believed to be an urban legend.
- "There is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will." -- Albert Einstein, 1932.
- “Fooling around with alternating current (AC) is just a waste of time. Nobody will use it, ever.”, Edison, 1889
Non-technical

- "I'm just glad it'll be Clark Gable who's falling on his face and not Gary Cooper." -- Gary Cooper on his decision not to take the leading role in "Gone With the Wind."

- "The concept is interesting and well-formed, but in order to earn better than a 'C', the idea must be feasible." -- A Yale University management professor in response to Fred Smith's paper proposing reliable overnight delivery service. (Smith went on to found Federal Express Corp.)

- "A cookie store is a bad idea. Besides, the market research reports say America likes crispy cookies, not soft and chewy cookies like you make." -- Response to Debbi Fields' idea of starting Mrs. Fields' Cookies

- "We don't like their sound, and guitar music is on the way out." -- Decca Recording Co. rejecting the Beatles, 1962.
Finally - Things that are feasible and should (could) happen

There will be more PMUs

• Arun talks about one in every substation like China
• Ed Schweitzer talks about the 10s of thousands of potential PMUs

Relays can become generally adaptive and cease to be as involved in exacerbating cascading outages. Backup protection can be supervised. Power System Control can and should be done with redundant controllers and signal paths like aircraft control systems. The new Infiniti Q50 has a steer-by–wire system with three independent electronic controllers.

Big data will come to PMU systems (in spite of ARPA_E reviewers). WECC is planning to archive 150,000 measurements a second.
and

- SIPS (RAS, SPS) can and will be coordinated with PMUs
- The linear estimator is an attractive data validation scheme for virtually all PMU applications
- Simulation results can be made to agree more closely with the real world by validation of models using archived data
- Operator alarms and alerts can be produced for
  - Oscillation
  - Angle limits
  - Voltage violations
  - Etc.
- At 30 times a sec synchrophasor data can be used for equipment monitoring and asset management (condition based maintenance) e.g. $l^2t$
- I suspect Sandeep and others will find techniques to protect synchrophasors data from cyber attack, at least temporally. Cyber security will be an ongoing issue. It’s a competition among clever people
From the MIT study,

• “With rapidly expanding connectivity and rapid evolving threats, making the grid invulnerable to cyber events is impossible, and improving resilience to attacks and reducing the impacts of attacks are important”

• “While privacy discussions in the popular press focus on consumer electric usage data, control over grid information is arguably more important”
Second Thoughts

• At this point I was going to pick on some streams of research that I was sure were not going to pay off and poke a little fun at them. I had some funny pictures

• But I realized that people who predicted progress and were wrong were not recorded in the previous lists- it was the naysayers who looked foolish.

• So if your idea is out of the box hang in there you may be right
Some belated thanks

• I have been informed I am supposed to retire after this symposium and although I do not intend to I assume this is my last chance to do this.

Thanks to:

• Alfred P Sloan. I would not have gone to Cornell without his scholarship. He was still alive when I was a student. I met him.

• Larry Dwon. A Cornell alum who was Manager of Engineering Manpower at AEP in 1976. He allowed me to be a faculty Intern at AEP in 1976-77. Without that I would not be standing here. Joe Eto asked me how so many good people managed to work at the old AEP. I think we were interrupted and I never answered.

• My guess would have been Philip Sporn. “AEP CEO 47-61 an executive with an engineer's knowledge he kept AEP among the early adapters of new technologies, including advanced generators, high-voltage transmission lines, and interconnection of his company's system with other utilities.” He was one of very few non-academics elected to membership in both the National Academy of Sciences and the National Academy of Engineering.

• Many colleagues

• And even more truly remarkable graduate students

Thank You for Coming